FINAL REPORT

FRAAI-WERK: DESIGN OF A LAMP CUSTOMIZATION TOOL

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EXECUTIVE SUMMARY

Introduction

A new era in terms of product design, production and consumption has started. In contrary to mass-produced goods, unique and personal products are becoming highly desired. People are willing to spend more on items that satisfy their specific preferences and distinguish them from others. This phenomenon is especially prevalent for cosmopolitans - young people with high income. They are consumption-oriented, ambitious and like to show their own identity and status. Regular retail stores don't provide goods that satisfy their needs, online shopping offers more possibilities however comes with many limitations. The crucial one being not able to experience the product and it's qualities (e.g. size, texture, fit) before the purchase. Fraai-Werk offers services tailored for the needs of this very customer segment. High quality, designer lamps that the client can customize to meet their own preference.

This project provides a solution for an online customization tool that allows cosmopolitans to design their own unique lamp. It aims at achieving high preference fit and enjoyment of the process.

Requirements

A literature study as well as 3-step user research was performed in order to elicit system requirements from target users. The research consisted of contextual inquiry exploratory interviews, lamp designing creative workshops (co-constructing stories method) and an online survey focused on lamp customization attributes. The results show that what customers require from a product customization tool is first and foremost **preference fit.** They need to be able to create a product that meets their expectations and needs. The system should thus provide:

- **Inspiration and help.** The system should support the users when they need inspiration during the process. Help and meaningful information about the impact of the user choices in the final product and its fit should also be provided.
- **Freedom during customization process.** As people have different needs and different levels of knowledge the configurator should enable the user to begin the customization process either from scratch or finished products. In the specific case of lamp customization it is important for the target customers to decide on: the aesthetics of the product (by customizing shape, color, material, dimensions),

the type of the lamp, the purpose of the lamp and the type of light. They should also be able to choose the order of the steps they want to follow during the customization process.

- **Trustworthy visualizations.** The biggest drawback of online stores is the uncertainty about the actual product. Pictures and models can be misleading. The system should provide rich illustrations and prototypes to let the user understand the final outcome of their customization. These representations should be realistic and trustworthy for the customers. It is especially crucial for them to ensure that the lamp fits their interior.

Design

We provide a solution that aims at ensuring that the user designs a product that fits both their needs and the interior design of the apartment. We focus on the idea of customization in context. Our proposal is a tablet application with the support of Augmented Reality (AR) to show the customized lamp in the context for which it is intended. The App meets the aforementioned user needs in the following way:

- **Inspiration and help.** Pre-designed lamps can be browsed and visualized in context to get inspiration. Relevant advice is provided by the app during the customization process. The tips adapt to the attribute that is being edited and the choices made by the user. The process of designing a lamp starts with a type of "wizard" that guides the user through the first steps that are crucial to start the customization. This wizard guides users to first choose a lamp type and correctly place it in the context.
- **Freedom during customization process.** The 6 most relevant customizable attributes are available in the App. Users can choose in what order they want to customize it and at which point of the customization process they want to get inspired or browse their own saved designs. They can also choose whether to start a lamp from scratch or from a pre-designed model.
- **Trustworthy visualizations.** Our app provides visualizations that increase the level of realism according to the amount of customization choices made. To ensure that the designed lamp fits the users' room interior, the visualizations are shown in context in one of two ways: live, in the form of camera view and augmented reality model of the product and static, as an automatically taken photograph of the space. The customer can easily change from one view to the other according to the use case.

Results

The solution proposed was prototyped in low and high fidelity. The prototypes were tested and improved in 5 iterations on which 16 users participated. Users found the interface intuitive, easy to use and simple. They enjoyed the customization process and expressed that the App would enable them to create a lamp that is personalized and different from the ones they could find in a store. Furthermore, most of them stated that the real lamp was exactly what they expected considering what they had visualized in the App.

Conclusion

The App designed is technologically feasible in terms of hardware and software. The visual design of the interface, the options available in each attribute level, and the order in which the wizard teaches the user how to use the App were carefully tested and are ready to be implemented. The only exceptions are the light representations, the auto-save function and the price visualization.

We believe that this application would enhance Fraai-werk customers experience by increasing the chances of preference fit.

CONTENTS

1. INTRODUCTION

A new era in terms of product design, production and consumption is starting. In contrary to mass-produced products, small-scale decentralized and personal production processes are becoming highly valued. More and more products are brought to the market, that can be personalized and customized, as for instance bikes, keyrings or furniture. The start-up company Fraai Werk recognized that development, aligned it's business strategy accordingly and is selling customizable lamps.

Several studies confirmed, that customized, self-designed products are valued more by the customers than standard products. The willingness to pay is higher for self-designed products than for standard products (Franke and Piller, 2004; Schreier, 2006). One of the most relevant reasons for this phenomenon is the *preference fit*. Customers perceive the value of self-designed products as higher, when they meet their preferences (Franke & Schreier, 2010).

Including customizable products in the portfolio creates challenges and demands changes from the provider. Pre-designed products can be presented to the customers easily by putting them in a physical store or showing pictures of the products in an online shop. A customizable product in contrary is not produced yet, when the customer is buying it and can thus not be shown. The customer will see the final product only after it was customized, produced and purchased. Therefore, it is of high importance that customization tools enable users to configure their products, ensuring that they deliver a high preference fit at the end.

The main goal of this project is to design a tool for the Fraai Werk company, that enables users to self-design lamps that deliver a high preference fit. In particular, the goals are:

1. To explore, prioritise and select a set of requirements for the customizing tool.
2. To conceptually design a tool, that meets the selected requirements.
3. To build and evaluate a prototype of this tool.

In order to achieve these goals, it is necessary to select which parameters of lamps are interesting for the target group users to customize. Furthermore, it is necessary to select the adequate amount of parameters and their levels. They should provide the users with a good amount of choice freedom without transforming the choice into a burden. The second challenge is to design a customization tool, that ensures the fit of the user needs into the product, and it is both feasible, and out-of-the-box. We want to introduce a novelty factor that could be implemented in the near future. Therefore, technologies should be chosen carefully and prototyped within the timespan allocated for the project.

1.1 TARGET GROUP

Based on the mentality model, cosmopolitans were chosen as a target group[1]. Cosmopolitans are citizens of the world who have growth, experience, success, materialism and enjoyment as core values. This group consists predominantly of young people with high income. They are ,consumption-oriented materialistic and technology-

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[1] The model defines group classifications of Dutch consumers based on socio-economic characteristics such as age, income and gender. The full description of the Cosmopolitan group can be found at http://www.motivaction.nl/en/what-we-do/mentalty/cosmopolitans

minded, impulsive and adventurous, status-conscious and they value art and culture. Furthermore, they are ambitious and like to have their own identity and status. They are socially and politically engaged, internationally oriented and networkers by nature.

1.2 CLIENT

Our client is Fraai-Werk, a startup company based in Rotterdam. Their members are Charl Smith, Faria Rampersad; cooperating currently with a creative director (WHI Agency) and a marketing company (Merketingvisie). As described earlier, their aim is to provide a service where

their users can customize their own lamp and buy it online. Additionally, the lamps are occasionally available on design/ lifestyle markets. Weekly meetings are scheduled with the client, in order to ensure that the project is on a good track.

1.3 APPROACH

A user-centered design approach was followed in order to achieve previously described goals. First, a set of requirements for the customization tool was gathered. Second, these requirements were used to create a conceptual design. Afterwards, the conceptual design was prototyped, tested and improved in quick iterations. The diagram below provides an overview of the complete design process that was followed.
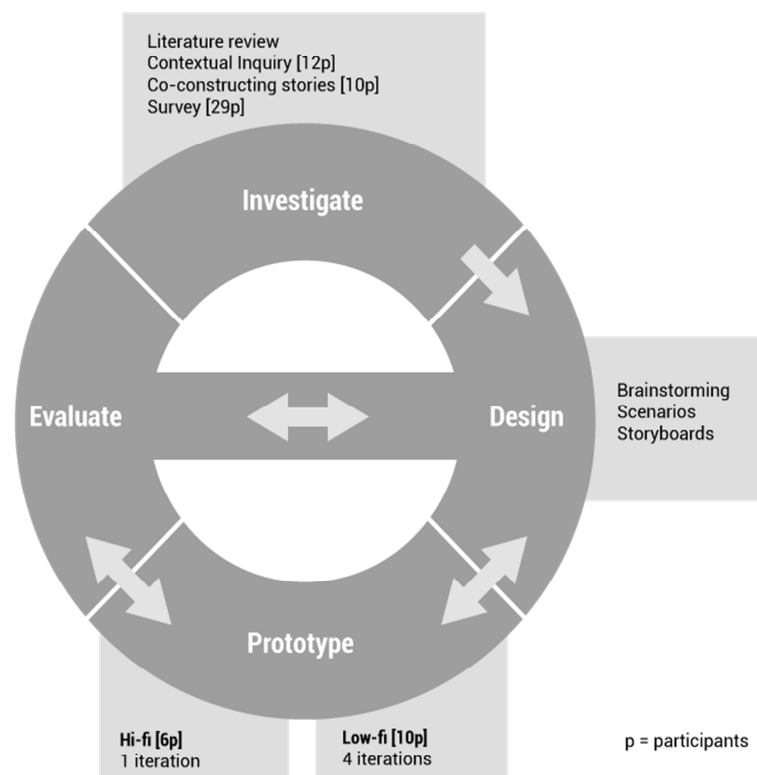
2. REQUIREMENT GATHERING

Three groups of stakeholders involved in the design process were considered. These include the general public (i.e., previous findings from the literature), final users of the customization tool and designers. Designers were considered because they might be designing some pre-made elements and finalizing the custom lamp design before sending the design to the 3D printer. The requirements were selected from both literature and user research. The main research question guiding these studies was: What are the requirements that a customizing tool should meet in order to provide customers with a positive customizing user experience?

2.1. LITERATURE RESEARCH

In the first step, a literature review was performed in order to collect requirements for customization tools, that are based on scientific work and formerly performed evaluations. Previous work gives insights about the motivation to buy customized products, how decisions are made in a customization process and how it can be supported. Furthermore, the literature gave important insights about differences in needs of novices and expert users. Additionally, several practical principles could be collected, that should be considered when designing a customization tool.

2.1.1. MOTIVATION TO BUY CUSTOMIZED PRODUCTS
There is an increasing tendency to allow consumers to customize their products online (Wind & Mahajan, 1997). This is effective, because consumers are willing to pay extra for products that they have customized according to their preferences (Schreier, 2006; Franke & Schreier, 2010). The added value of customization can be explained with the Ikea effect (Norton et al., 2012). The Ikea effect means, that own labour and effort, that is put into a product, increases the liking and its perceived value. According to Norton et al. (2011) there are several reasons for this phenomenon: (1) some labour is enjoyable, (2) labour allows for product customization and (3) work is perceived as a rewarding activity. A crucial factor for the Ikea effect is, the extent to which the labour successful. Norton et al. (2011) could show, that the Ikea effect occurs for both utilitarian and hedonic products.

The Ikea effect was further investigated specifically for the customization of products (Franke & Schreier, 2010). It was found that, the effort put into the customization process alone does not increase the perceived product value. Franke and Schreier's (2010) study suggests that the perceived value of a customized product is impacted amongst others by how enjoyable the customizing process is and if the end result fits the customers' expectations (preference fit). Both, an enjoyable customization process and a high preference fit result in a higher subjective product value (Franke & Schreier, 2010). The authors explain the increased economic value of customized products with the positive and rewarding experience, that creates a positive mood. This is projected onto the assessment of product's value. Further, the amount of effort put in the customization process plays an important role. Depending on the preference fit of the product, the process effort has either a positive or negative effect on perceived value of the product. If the preference fit is high, the process effort is interpreted as positive accomplishment and adds to product value. In the case of low preference fit effort creates a negative effect and reduces the subjective value of the product.

2.1.2. DECISION-MAKING WHEN CUSTOMIZING PRODUCTS
Product customization requires consumers to build their own product by making decisions about its attributes, like the colour, size, dimensions etc. Each attribute usually has a set of options from which to choose, therefore, customization involves decision-making processes. These decision processes can complicated for users.

The difficulty of decision-making increases as the number of alternatives and attributes increases, if a specific attribute is difficult to process, if there is uncertainty about the values of attributes or if the number of shared attributes is smaller (Bettman et al, 1991). Having too many choices can be demotivating for customers and additionally leading them to decision errors. Considering too many attributes, considering attributes at all, considering only justifiable attributes and considering too many options can lead to decision-making errors because there is too much to decide (Ariely & Norton, 2011). People feel more motivated to buy a product or make a decision when they are offered a limited amount of choices than a more extensive one. Iyengar and Lepper (2000) indicate that an optimal limit of options is six; Malhotra's study (1982) revealed that dysfunctional effects of information overload emerge when customers are provided with ten or more alternatives in the choice set or with information on 15 or more attributes.

The order of attribute presentation can also influence the decision-making during the customization process. Levav's *et al.* (2010) research showed that when attributes with relatively few options follow attributes with relatively many options people are more likely to accept default options than when this sequence of attributes is reversed. The tendency to accept the default appears to increase through the high-to-low sequence despite the fact that attributes with relatively few options can be theoretically less costly to consider. These findings indicate that if the aim is to let the users customize their own products as much as possible, attributes with more options should be presented first.

2.1.3. DIFFERENCES BETWEEN EXPERT AND NOVICE USERS

To what extent users should be involved in the design process and what type of decisions they should be able to make, depends on the type of user (Randall et al, 2005). Some customers have more knowledge about the product than the others. The customization interface should be fitted to their needs and expertise levels. Randall et al. (2007) state that in parameter-based systems amongst others the perceived comfort and preference fit increase with the expertise of the user. This indicates that expert customers are comfortable using parameter-based interface. They understand how the manipulation of each of the actual design parameters influences the product. Novice customers however, do not possess the necessary domain knowledge. They should be able to express their needs in terms of desired values. The system then should itself configure the product that is going to meet those needs. Some customers with very low expertise even prefer not to customize products at all. Providing consumers a tailored interface is often accomplished by having consumers self-select into a choice of interface most suited to their abilities and needs.

2.1.4. TEACHING THE CUSTOMER

In order to make conscious choices customers need to understand the design space, the parameters and the trade-offs among attributes. Helping clients to understand how their choices affect the product results in a better product fit, thus higher satisfaction. This can be done by providing additional meaningful information during the customization process. Relating to other customer choices will help them understand more abstract attributes (Randall et al, 2005). In general, consumers are much more comfortable with a statement such as "I want my computer to have slightly more than average storage space." (Randall et al. 2005).

2.1.5. MULTIPLE ACCESS POINTS FOR CUSTOMIZATION

Not all customers are interested in fully exploiting the potential of customization. Randall et al. (2005) suggests to provide several initial designs (starting points) from which the customer can begin the customization process. He distinguishes between three types of starting points. (1) Free-form design interface allows manipulating nearly every parameter of the product including its basic shape and style. (2) In a combined configuration, the customer is constrained with a pre-specified product architecture but can select certain attributes, for example, colours and

materials. (3) In refinement from starting points, the user can choose a pre-defined style they like and then make changes to it.

2.1.6. INCREMENTAL REFINEMENT
Customizing a product is an iterative trial-and-error process and can be a cognitively challenging. Randall et al. (2005) suggest several tools to support and ease this task. Allowing consumers to bookmark their work helps them to recover previous design alternatives. Side-by-side comparison of saved configurations provides a simple, visual way to support the sensitivity analysis. The system can also provide a few pre-selected "short cuts" that automatically find certain e.g. lighter, less-expensive, and faster configurations as improvements to the current configuration.

2.1.7. REALISM IN PROTOTYPES AND CONTEXT
By their very nature, customized products are likely to be unique. This makes it difficult for consumers to anticipate their post-purchase experience (Randal et al., 2005). Clients cannot just go to a store to test the exact product. It is crucial to provide rich illustrations and prototypes to help clients understand the outcome of their customization. Additionally, several product attributes can be intangible like smell or a fit which makes it hard to show or explain them on a computer screen. To help customers avoid bad surprises, it might be necessary to send them samples of the product or advise them to visit a retail store, talk to a consultant.

According to Lu and Smith (2007, 2008) it is not only important to present the products in realistic representation. Also, the context in which the products are presented has to be considered. Lu & Smith (2007, 2008) compared in their studies traditional e-commerce stores, in which products are presented without any context with virtual reality and augmented reality (AR) systems. Participants had the task to search for products, interact with them and acquire product information. It was shown, that the overall evaluation and the level of satisfaction is higher for the AR system. According to Lu & Smith (2007, 2008) an AR e-commerce system provides more visual information to online shoppers than the other two systems. Further, participants are more confident about their shopping decision in the AR condition. These results suggest that it is important to present products in online stores as realistic as possible and in a realistic context.

2.2. USER RESEARCH
To achieve the our first goal of understanding the customization process and customer needs we conducted an exploratory research. In this phase we performed two qualitative studies: contextual interviews (section 2.2.1) to explore users' thoughts and interests in customization products and a participatory study to gain more insights into the customization process of lamps (co-constructing stories, section 2.2.2). Finally, in order to prioritise user needs and define a final set of requirements, we ran an online survey (section 2.2.3).

2.2.1. CONTEXTUAL INQUIRY

INTRODUCTION
The literature review provided us with insights about the customization process, why is it valuable for people and how to implement it. However, these are findings related to the general public and not for cosmopolitans in particular, which is our target group (see 1.1). The cosmopolitans are a particular group that might have specific needs. Therefore, we started our design process with a contextual inquiry (CI). After the target group is recognized, a CI helps to uncover user's needs. Those might be embedded in their mental models, tools, their terminology, methods, goals or values.

Furthermore, designers can be involved in the customization process. They might design several elements in the customization tool, provide guidance to the user and finalize the customer design to ensure customer satisfaction. For those reasons, we included them in the contextual inquiry.

The main questions we wanted to answer were, if the customers had previous experiences with customization, what type of products would they like to customize and what aspects they would like to customize and their opinion about design products. For the designers, we chose to interview those who had already worked with customization. We asked them about the customization process, and what aspects they considered to implement.

METHODS

PARTICIPANTS

12 visitors (customers) and 3 designers at the Dutch Design week in Eindhoven were interviewed. Three different locations where customizations tools were used, were chosen for the interviews. The average age of the participants was 37 years (with a minimum of 25 years and a maximum 66 years).

PROCEDURE & ANALYSIS

A semi-structured interview was conducted. The protocol and guideline questions are described in Appendix A1. The answers of the participants were analyzed by creating an affinity diagram.

RESULTS AND DISCUSSION

USERS

Users found important to have products characterized by uniqueness, richness of ideas, creativity, nice-to-look features, individuality, style, an artist signature, optimization for small spaces, reusability of the material, simplicity and elicitation of different feelings. They thought that functionality is the most important aspect of a product. However, people like to integrate it with style.

"For me, functionality is the most important. All the other parameters combined create style… I like to integrate functionality with design (style)" - Participant 8, female, 39 years old

Tailor-made products are perceived as valuable and desirable however, they are considered too expensive to be purchased. This is why most participants do not buy customized items. People prefer to have do it yourself items because they save money. Things that can be assembled or disassembled are easy to transport, but sometimes the instructions to assemble them are difficult. It is good that some stores offer to assemble the items. Some people like that they can make something else with the pieces, something original. They can also get inspiration.

The participants mentioned other items where they imagine customization. These included tables, sofas, lamps, kitchen, tent, clothes, beds, cars, doors and radios. Participants also suggested several attributes to customize based on their needs. These included the case of the product, form, material, color, size, shape, style, amount of light, how to hold the product, and the products functionality. Also, regarding material, participants preferred metal and wood over plastic. Also natural fabrics were seen as favourable. Furthermore, people prefer to buy raw materials for their creations than reusing materials.

The amount of choices should be limited to avoid complexity. Furthermore, visualizing the item in context can help to make a decision. The amount of customization needed depends on how finished the product is and the time the customers have available to design their own product. Furthermore, it is difficult for non-skilled people to visualize the end product. When it is too complex, an expert who can visualize it or support from a tool is needed.

People seek quality in their purchases, they want to have something that is built right and that looks good. The designer can also be a source of inspiration. Furthermore, they value the personal connection with the designer/expert. People believe that customization should be constrained. Some parameters are more difficult to change and ensure that it will still look good.

"If the price is high... ok, it is worth. Because we discussed the size how it should be and everything with the expert, how to build it (about the tent). So ok, its more expensive, but it is also an expert opinion who will build it right. Then the whole process is worth the money. You have sometimes actually a personal connection with the person that's doing the work for you. That makes up for the extra cost." - Participant 2, male, 27 years old

Finally, it depends on the product if they buy online or in retail stores. Usually trust in an online service is an important factor to choose where to buy.

DESIGNERS

Designers believe that the general public is looking for something to define themselves and express their identity.These items should be unique but not too extravagant. Most customers are enthusiastic about this idea. Nevertheless, they also provide customers with the option of buying something already-made. Furthermore, most of customers had positive reactions towards customizing items, but they have to have an specific mind set-up to buy them.

"I think everybody is looking for something to define themselves, to express their identities. especially in Holland you should not be too outspoken about it. It should be something that makes you different from others... Otherwise you can just take one of the products we already made, where we took the decisions. " - Designer 1

The customization tools currently used are web or pdf based, smart and easy, and the number of options is limited. During customization, the more the parameters, the harder it is to visualize the end product. Designers constrained the amount of customizable parameters. The levels of these parameters ranged between 3 and 8. In the case of fabrics it went up to many textures and colors. Due to the many parameters, if there is no visualization tool, customers can only imagine the outcome of the product. Usually designers have the skill of imagining how an object would look like before building it, but it can be troublesome for others. Designers can control the final outcome by letting users change predefined elements. Designers tried to avoid this problem with visualizations of the customized product. In current customization tools, some designers aimed to have realistic representations with meaningful information and accurate feedback, and others aimed to have simple drawings with just lines.

"Many people is just happy that they can make a decision. We are visual people, we have the skills and the image in my head to make it happen. But usually people don't. You need the skill, if you cannot visualize it, the disappointment could be big." - Designer 1, garment customization

It is also important for designers to have an artist signature, therefore, they find it important that the designer takes certain decisions. The more people involved in the design process, the less designish it feels.

"We were looking to have some signature, so we think that it should not be completely open, the designer should make some decisions. " - Designer 1

The customization process is separated into several steps. These partners sometimes ask them to make expositions. Furthermore, the customization is sometimes in parallel with the production, but not always. Some designers had both an online and retail store. They cooperated with retail stores to let customers try their products in real life. Other designers let their customers choose the attributes directly on the store or at their stands in expositions, and they assisted them with the process.

"Spiked started as only online service and realized they need to cooperate with retail stores to deliver the whole experience. the same customization tool available online and in stores. The real experience of riding the bike happens in the store, and so does the selling point" - Designer 3

SUMMARY OF RESULTS

Most participants valued the concept of customization, but they find having a competitive price crucial. Because of the price, they are also more likely to customize large-impact products. When customizing, people value the customization of both functionality and style. Style features should promote uniqueness and creativity. It is also important to limit the amount of choices to avoid complexity and to provide a proper visualization of the customized product. This visualization should provide accurate feedback to let the user see the impact of every choice on the final product. People care about the quality of the end product, so they often seek advice from an expert and they value their personal connection with him. Furthermore, seeing the final product in a store is helpful to avoid disappointments due to misconceptions or incorrect visualizations. Finally, despite their preferences for customization, sometimes people are not willing to spend time customizing, so already made products should be also available.

DISCUSSION

This contextual inquiry shed light in the thoughts of people related to customization, however, little information was gained related to customization of lamps. Participants had a hard time thinking about lamps, especially if they never customized one. Furthermore, some participants were not directly the Fraai-Werk customers target group, because they would not buy customized products unless the prices went down. In order to gain more detailed information about lamp customization in particular and what attributes to customize, other studies were conducted. The co-constructing stories method was used to situate users in the context of customizing a lamp and to get more insights about the customization process. Furthermore, a survey was designed to quantitatively select the most important attributes or needs for the customization.

2.2.2. CO-CONSTRUCTING STORIES

INTRODUCTION

The results of the contextual inquiry provided us with information about users' opinions about design products, previous experiences with customization, and type of products and attributes that they would like to customize. However, it did not elicit needs related to the customization of lamps in particular.

It is for this reason that we performed a second qualitative study, using techniques proposed by the co-constructing method (Buskermolen & Terken, 2012). This participatory technique enables the elicitation of user feedback and suggestions during early stages in the design cycle. It is based on the assumption that users can make better judgements about new concepts when they also consider their previous experiences. It is for this reason

that the co-constructing stories sessions consist mainly of two phases: a sensitization part to make participants think about their past experiences, and an elaboration phase on which envision the future.

The goals of our co-constructing stories study were to elicit all possible user needs and lamps' attributes for lamp customization, to understand the lamp customization process and to gain insights into the types of visualizations used and the opinions on customizing lamps in a store and online.

METHODS

MATERIALS

The set-up of the room where the sessions took place included diverse materials and tools (see Figure 1). The materials available were selected to enable the observation of the participants' use or interest in:

- Different levels of abstraction: tools for the creation of low fidelity visualizations (e.g. papers to draw, legos, clay), mid-fidelity prototypes (e.g. 3d models, sketches) and for the creation of high fidelity ones (e.g. photos, lamps).
- Prototyping and visualization modalities: tangible (i.g. lamps, 3d models) and non-tangible/visual tools (drawings, pictures).
- Possible lamp attributes: materials, colors, shapes, etc. represented in different levels of abstractions and modalities.

From the attributes and user needs elicited in a design team brainstorm session and the contextual inquiry interviews, a list of attributes and needs was created. This list was used as a checklist during the sessions. The assistant check-marked the attributes or needs mentioned by the participant and also added new ones. A table with the levels of abstraction of the tools and their tangibility was also included to register the types of prototyping tools and visualization used by each participant.

Figure 1. Set-up of the room where the co-constructing sessions were conducted.

PARTICIPANTS

10 participants in total were recruited, 5 male and 5 female. Two different types of participants were invited: users (participants 1 to 5), which were potential customers of Fraai-werk's lamps, and experts (participants 6 to 10), who were industrial designers with knowledge about lamps and lighting.

PROCEDURE

Each participant attended individually a session of around 35 minutes. During the session participants interacted with the available materials, a facilitator, who instructed and interviewed them, and an assistant who was taking notes and video-recording.

The sessions consisted of 3 main parts (protocols can be found in appendix A2.1). First, with the goal of sensitizing participants, a set of questions about their previous experiences choosing and buying lamps and ideas about lamp customization were asked. Secondly, the elaboration task took part. Participants were asked to imagine that they had just moved to a new apartment or that they wanted to redecorate their current one. Their task was to design their own lamp by customizing it and think-aloud during the process. They were encouraged to use any of the available tools to help their design process. Finally, after finishing the customization process a few questions were asked: about their customization experience during the elaboration phase and about their preferences for retailers (physical stores) or online shops to buy lamps of this type. The experts group was additionally asked about the limitations in customization that they would prefer to set, and the aspects that they would not "negotiate" with a client that is customizing a lamp.

ANALYSIS

After the sessions, the data gathered was typed (including both quotes and observation notes) and analyzed in 4 main groups:

- Attributes and needs
- Design process and steps
- Visualization and prototyping tools used
- Online vs store information

For all the groups affinity diagrams were created. Patterns were identified, categorized, and coded in order to uncover themes or categories of information.

RESULTS AND DISCUSSION

ATTRIBUTES AND NEEDS

The first set of attributes and needs created from the contextual inquiry and brainstorm results was reorganized and extended using the input from users during the co-constructing stories study.

As regards which aspects of customization designers would prefer to decide on themselves and which can be left for the customers, designers expressed conflicting opinions. Two of the designers said that they would allow the customer make all the choices. On the contrary, others stated they did not feel like the customers should make any choices, rather than that they should give some general requirements and the designer will make the actual decisions.

Some of the participants from the users group stated that they should have limited options to customize. Reasons for this were the designer expertise in the lighting, aesthetics and technical aspects of lamp but also because it is harder to make decisions when having too many options. Among the things mentioned by designers, aspects that could be customized by users are:

- colors
- materials
- shape

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- size
- context
- how to use the lamp
- type of the lamp
- type of light
- color temperature
- sockets

Often mentioned was also the co-operation of the designer and customer. Both customers and designers felt comfortable about a close cooperation of the two when the customer explain his needs and wants and the designer works using his expertise to fit them and create a product they are proud of.

The decision left to the designer according to designers themselves should be:

- technical parts of the lamp
- shape
- spectrum of light
- everything related to electricity (socket, cord, power)
- the functional part of the lamp

DESIGN PROCESS

When customizing their own lamp, each participant performed different actions in a certain. All the tasks performed were classified in groups of actions. As not all participants performed actions from all the groups, participant numbers are indicated in each case:

- Recalling own needs or requirements (Participants 1, 3, 4, 7, 8 and 10): this group includes tasks in which participants considered their own needs and requirements for their lamp. Some participants (1, 7 and 10) considered in particular the context where the lamp would be placed (distribution in the room, color of the walls purpose of the lamp).
- Looking for inspiration (Participants 2, 3, 4, 6, 7, 8, 9 and 10): 8 out of 10 participants used pictures of lamps and rooms to get inspired for their own design. Most of them did this at the beginning of the process, except for participant 10 that did it closer to the end.
- Exploring the available tools (Participants 9 and 10): 2 participants took some time to explore all the materials available in the table early in the design process.
- Focusing on characteristics of their lamp (Participants 1, 2, 7 and 10): some participants explicitly reported specific attributes that the lamp would have (e.g. color, materials).
- Going back to previous decisions or iterating (Participants 3, 6, 9 and 10): 4 participants repeated the process or parts of it.
- Visualizing and prototyping their ideas (all participants): participants used different tools to visualize, prototype and communicate their customized lamp (see "Visualization and prototypes" below)

No patterns were found in the order of the steps. Even though differences in the design processes between the experts group and the non-experts/customers group were expected, no difference was observed. Some participants from the users group experienced difficulties during the customization process (Participants 3, 4 and 5). The reasons they gave for this were that they did not know exactly what they wanted, that it was hard for them to make decisions, even though they knew what they did not wanted (for example one of them pointed at a few pictures clearly stating that s/he did not wanted something like that). Besides, one of them (P5) expressed that

s/he could not imagine exactly how the lamp would be at the end and therefore, he was curious to try different options and assembly it him/herself. Other participants also mentioned that they like to have a product overview or prototype before buying it.

There were different ways in which participants started the customization process. Some would use provided examples of existing lamps and samples of materials, shapes and colors as inspiration and starting point. Other participants already had an idea what they wanted and started their design process from scratch by drawing or building it. A combination of those two also appeared.

VISUALIZATION AND PROTOTYPES

- Different levels of abstraction: tools for the creation of low fidelity visualizations (e.g. papers to draw, legos, clay), mid-fidelity prototypes (e.g. 3d models, sketches) and for the creation of high fidelity ones (e.g. photos, lamps).
- Prototyping and visualization modalities: tangible (i.g. lamps, 3d models) and non-tangible/visual tools (drawings, pictures).
- Possible lamp attributes: materials, colors, shapes, etc. represented in different levels of abstractions and modalities.

Participants used both lo-fi and hi-fi prototyping tools or a combination of both. For example participants would draw the shape of their lamp on paper and use a real fabric to explain the material (see Figure 2). Additionally they verbally explained what they wanted

Drawing on paper with markers, pencils was used by all of the participants. It allowed participants to easily show what they meant if they already had an idea what they wanted or if they could find the materials that would fit their needs (fabrics, shapes, pictures)

Lego blocks were used to prototype the shape of the lamp and to explain it's placement in the space.

Realistic pictures of actual lamps, fabrics, contexts were used by 9 out of 10 participants. They served often as inspiration and a starting point to further designs. None of the participants actually chose to settle for a ready lamp. If they saw a picture of a one they liked they would draw on top of it or explaining what they would change in it or what they would take from it for their design.

Real objects - lamp parts, actual lamps, bowls, materials were used to build prototypes, lamps shades and bowls severed as shapes, fabrics helped explain the properties of materials participants wanted to use for their lamp.

Some participants also mentioned the lack of possibility to experience the light effects. They wished to know how the light will behave with the fabrics and shapes used.

Participant 4 stated several times to using a computer/online program as an advantage among others to have a better choice selection.
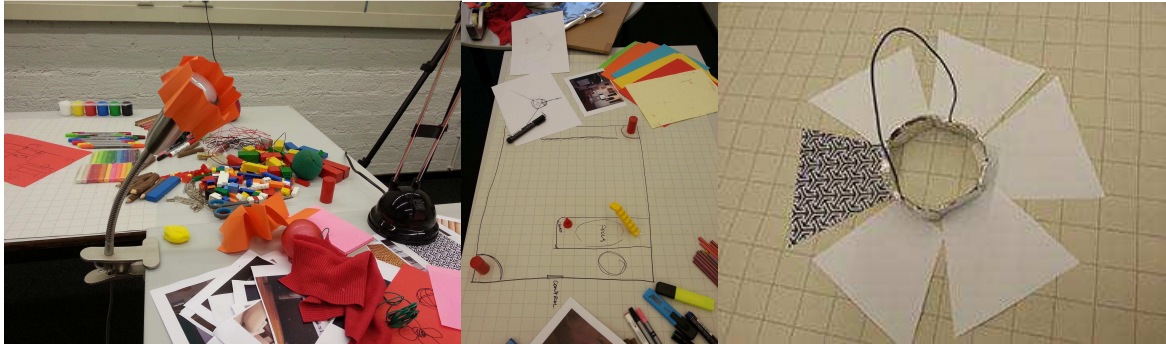
Figure 2. Samples of prototypes and visualizations created by participants

ONLINE AND STORE CUSTOMIZATION

There were participants that indicated, that they would buy products online, but only under certain circumstances. It would depend on the type of product (e.g. electronic devices) and also if the brand or the product is already known. Several participants mentioned that they would not buy especially expensive products or products from a unknown brand without seeing them in real life before. So even, if these participants buy a product online, they first try to get a better impression of the product in a store. Advantages for buying in a store and as well for shopping online were mentioned:

Perception of products: The analysis showed that for 9 out of 10 participants an important reason for buying in a physical store is the perception of the product. Seeing the real product would give better information about the dimensions, weight, material and haptics of a lamp. The most crucial aspect seems to be that participant feel the need to see the effect of the light. This gives them apparently a better impression of the lamp the only seeing it online. However 2 participants mentioned, that also in physical stores it would be hard to choose the right lamp. The big amount of presented lamps next to each other would distract buyers and also avoid, that they can get a correct impression of the light effects.

Trust: 3 Participants would buy products online without having them seen in real life, because of a lack of trust. They are afraid, that the pictures are photoshopped and are not representative for the real product.

Looking for inspiration: One participant mentioned that especially, when he/she has no particular product in mind he/she prefers to visit stores to get inspiration there. On the other hand, there were also participants, who mentioned that they explore websites and online services like pinterest to get inspired about what product to buy.

Decision making: Especially when there is a lot of choices, as there is for lamps, for one participant it is hard to decide which one to buy. In a shop he/she can get a better overview over the offered lamps. This would help him/her to decide, which lamp to buy. In contrast, 4 participants believe they get a better overview over offered products online. Physical stores have restrictions because of the amount of space they have. Online more options can be found – also from designers from different countries. A big advantage online is, that different options can be compared, also in order to find the product with the best price. Further, often the feedback of previous buyers can be found online, which helps with the decision making.

Convenience: For three participants it would more convenient to buy a lamp in a store. Mainly because it can be used immediately. For other participants it would be more convenient to buy a lamp online, for instance due to a busy schedule. However, therefore it is necessary, that the products are delivered also in the country, in which the potential buyer lives.

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Individuality of products: According to one participant it would be only possible to find personalized, customized lamps online.

SUMMARY OF RESULTS

The results found during the co-constructing study indicate that the customization tool should:

- Enable the user to get a full and realistic impression about the product online (dimensions, weight, material, haptics, effect of the light)
- Let them see the effect of light
- Create trust in online representation/pictures of the lamps
- Support the user in the decision making process, e.g. by giving him a good overview over all the options and letting him compare different products
- Make sure, that customizing the lamp and buying it online is convenient (short process until delivery, shipping in all countries)
- Limit the customization of: technical parts of the lamp, shape, spectrum of light, everything related to electricity (socket, cord, power) and the functional part of the lamp. Leave this aspects for the expert designer.
- Enable the designer to give advice and help with his/her expertise to meet the users' preference fit.
- Support users in all the customization steps: recalling own needs or requirements (including the context), looking for inspiration, exploring the available customization tools, focusing on characteristics of their lamp, going back to previous decisions or iterating and visualizing and prototyping their lamp
- Let users iterate and decide the order they want to follow by themselves
- Let users pick by themselves the the starting point: (1) from scratch, (2) from a model (3) from an alternative (eg. picture of one lamp already designed).
- Help customers when they find it difficult to make a decision. Consider that sometimes they know what they don't want, more than what they want, they can identify things they like (inspirate them) and help them to visualize
- Enable users to draw and sketch, show realistic pictures and include Information about the light effect (how the light will behave with the fabrics and shapes used). Enable them also to combine the use of different tools.

DISCUSSION

The method and setup of the experiment had a few limitations. The selection of materials to represent each variable during the study was subjective and limited, as not all possible materials and pictures could be provided during the sessions. On the other hand, even with a limited amount of tools, some participants might have not seen all of them and therefore, might have chosen not the tools they needed the most but the ones that were in their sight. Finally, part of the results of this study were analyzed through observation. As observers used their own subjective perception, conclusions might suffer from cognitive bias.

2.2.3. SURVEY

INTRODUCTION
Results of previous studies provided us with information about customer needs in terms of which aspects of lamps would they want to customize. However, we still did not know which of them were the crucial ones for the potential customers. In order to answer this question we conducted an additional survey.

METHODS

PROCEDURE
The survey was conducted online over the period of 7 days (from October 30, 2013 to November 5, 2013). Participants were contacted through Fraai-Werk website (http://www.fraai-werk.nl/) and Facebook fanpage and through personal networks of the client and the researchers. Additionally people who took part in the contextual inquiry and volunteered their willingness to participate in further studies were contacted as well.

PARTICIPANTS
29 participants completed the survey (12 male and 17 female). The participants were aged 28,29 years old on average (SD = 2.49) and currently living in one of 9 different countries with the majority of 51.7% residing in the Netherlands. Majority (51.7%) of the participants household income was more than €3000.

MATERIALS
The survey consisted of 3 parts. First of all we needed to make sure that the participants taking part in the survey were in our target group. We asked demographic (gender, age) and household income questions. From the client's description of the target group could be concluded that his clients are often involved in creative tasks (at work or in spare time) thus we asked three question related to creativity. The participants indicated, to which amount their work contains creativity, if they like to do creative things and to which extent they perceive themselves as creative. Answers were assessed on a 5 point Likert scale from 1 (not at all) to 5 (extremely). Lastly we wanted to know the level of their expertise in lighting and if the ever customized or designed lamps before (and how).

In the main part of the survey we asked the participants to imagine that they were buying a lamp and had the chance to customize it. They should indicate how important it is for them to consider certain lamp aspects in the customization process. The answers were also assessed with a 5 level likert scale from 1 (not at all important) to 5 (extremely important). We included 19 customization aspects elicited from our previous findings (table 1). Those related to lamp's physical, and technical elements, aesthetics, lighting as well as price and personal values. The order of those aspects was randomized per participant in order to avoid ordering biases.

The last question in the survey was about the preferred way to buy their customized lamp (retails store vs. online). All the questions from the survey can be found in appendix A3.

RESULTS
In order to identify the most important needs and attributes an overall ranking of the items was created. Therefore, raw values of items were summed up over all participants and then ordered accordingly. That means, items on top of the ranking are over all participants very important, when customizing a lamp. Items on the end of the list are considered as less important. The five most important needs and attributes are (1) the beauty of the product, (2) the type of the lamp, (3) the purpose of the lamp, (4) the type of light and (5) that the lamp matches the interieur.

The complete list of ranked items including the ranking and means can be found in table 2.

	Item	Sum	Mean	SD
1	Ensure that your lamp is **visually beautiful**	129	4,45	0,57
2	Choose the **type of lamp** (e.g. desk lamp, night stand, hanging lamp, fixed/non-fixed location, etc.)	128	4,41	0,78
3	Decide about the **purpose of lighting** (e.g. if it will be used as a reading light, to create an atmosphere, to lighten up certain areas)	126	4,34	0,81
4	Choose the **type of light** produced by the lamp in terms of intensity, output and color	123	4,24	0,99
5	Adjust the lamp so that it **matches your interior** (furniture, room color, decoration, etc.)	120	4,14	1,03
6	The price of the lamp	112	3,86	1,09
7	Decide about the energy consumption of your lamp	105	3,62	1,08
8	Ensure that your lamp is original and creative	104	3,59	1,38
9	Choose the way your lamp will turn on and off (e.g. switch, remote, automatic)	103	3,55	0,99
10	Decide on the type of energy supply of your lamp (e.g. electricity, battery, solar, etc)process.	103	3,55	1,15
11	Be able to choose materials considering their quality	102	3,52	0,87
12	Manipulate the lamp's physical dimensions according to the context (e.g. size, width, height)	100	3,45	1,15
13	Ensure that your lamp is easy to clean	97	3,34	1,14

14	Choose the type of materials of the lamp	94	3,24	1,06
15	Be able to control the shape of your lamp	92	3,17	1,39
16	Have a unique lamp	91	3,14	1,36
17	Ensure that the lamp has a personal meaning for you	85	2,93	1,36
18	Choose materials considering their source	79	2,72	1,13
19	Ensure that your lamp has a designer brand or signature	53	1,83	1,04

Table 2: Ranked attributes and needs assessed in the survey, including the sum over all participants, the mean and standard deviation. The green marked items are highest rated and used for the further concept development.

CONCLUSIONS AND USER REQUIREMENTS
Below we describe each of the user requirements that the customization tool should meet.

1. PREFERENCE FIT
The system should make sure that the customized lamp at the end meets the user needs and expectations.

2. ATTRIBUTES CUSTOMIZATION
The customization tool should enable the user to customize the following attributes and needs according to their wishes:

    a. the beauty of the product (by customizing shape, color, material, dimensions)
    b. the type of the lamp
    c. the purpose of the lamp
    d. the type of light

It is important for them that they can customize their lamp to fit their interior.

3. CHOICE LIMITATION
The amount of decisions that users have to make should be limited to maximum 9 options at a time.

4. STARTING POINTS
The configurator should enable the user to begin the customization process from 3 different starting points:

    1. From scratch or free-form interface: which enables them to manipulate all possible attributes
    2. From a model or combined configuration: users can start using a predefined product architecture including already pre-defined values for certain attributes.
    3. From an alternative: users can refine their design by using a predefined alternative of an already designed lamp that they can make changes to.

5. CUSTOMIZATION STEPS
The tool should support users in all the following customization steps:

- recalling their own needs or requirements (including the context)
- looking for inspiration
- exploring the customization tool and customizable attributes
- defining specific characteristics for their lamp (attributes)
- visualizing and prototyping their lamp

6. VISUALIZATIONS

To begin with the lamp design, drawings and sketches are enough. However, the system should provide increasingly richer illustrations and prototypes to let the user understand the final outcome of their customization. These representations should be realistic and trustworthy for the customers. They should include the context where it will be placed and the light effects.

7. PHYSICAL PERCEPTION OF THE PRODUCT

Customers should be able to perceive the customized lamp in a tangible way before finishing the customization process. Samples or prototypes could be sent to them.

8. POST-EDITING AND ITERATION POSSIBILITY

Users should be able to go back to previously made decisions to make changes. The customization tool should let them iterate in the design process and allow them to bookmark their work to then go back to previous design alternatives.

9. COMPARISON

It should also enable side-by-side comparison of saved configurations and their characteristics.

10. CUSTOMER/DESIGNER RELATIONSHIP SUPPORT

The configuration tool should enable the user to feel supported by the designer, who could guide or advise the customer to ensure that the lamp meet his/her needs.

11. DECISION-MAKING SUPPORT

Customers should be able to see an overview of all the options and configuration tools. They must receive feedback on the impact of every choice they make in their lamp. The customization tool should provide meaningful information about the impact of the user choices in the final lamp and its fit. It should also provide shortcuts that automatically find configurations as improvements to the current configuration.

12. ADAPTATION TO EXPERTS AND NOVICES

The system should adapt to both types of users: those who think in terms of attributes (experts) and to need-based users (novices).

3. DESIGN CONCEPT

Available tools have attempted to address the need for customization and uniqueness of lamps. However they have several limitation, and often do not satisfy neither the requirements for customization systems nor the lamp-specific ones. Most of the existing solutions just provide large lists of options from which the users have to choose. Furthermore, these tools do not allow the user to see the product in the real context in which it will be used.

Given the aforementioned needs and the lack of lamp customization tools, we designed a feasible-to-implement customization tool that ensures user's *preference fit* and therefore is rewarding. Our focus was to achieve this by placing the product into context, addressing the level of realism required in each stage of the customization process and carefully selecting the options to be customized. By correctly representing the product, trust in the results of the customization process is created.

Although the end result of customization is highly valued, the customization process requires effort from the user, and therefore it is time consuming. Since the user would spend time and effort creating a lamp, our first goal was to create a customization process that is enjoyable. Enjoyment can be achieved by giving the user the freedom to choose what to customize, providing him with inspiration and guidance throughout the process, and finally, by making the customization tool intuitive and easy-to-use. In other words, the process should be semi-unstructured, inspiring, fun and rewarding; and the customization tool should be usable.

Such lamp customization tool was developed iteratively with a user-centered approach. Fist, a brainstorming was made and storyboards and rapid prototyping were used to select the concept that fits best all the user requirements proposed in previous sections. From this process, a tablet application supported by augmented reality was chosen as the most appropriate and feasible. Second, rapid prototyping with different fidelity levels (i.e., low-fi and mid-fi) and user tests of those prototypes were used to refine the selected concept and to design the interface and interactions of the customization tool. Finally, the final concept, interface and interactions were represented using a video prototype.

3.1. DESIGN ALTERNATIVES

As result from a brainstorming, we generated a first set of ideas, ranging from holograms to depict the lamps, tokens to place them into context, brain reading to decode their mental image of the lamp or their preferences, and tablet Apps with augmented reality.

From these ideas, two were selected on basis of their potential of fulfilling all the user requirements. Several scenarios and quick prototypes were made for each idea. Finally, a list of advantages and disadvantages was made for both. This process leaded us to the selection of one of the two.

The first selected idea was a set of tokens representing an attribute of the lamp each, and a hologram interface to show the lamp. The tokens could be ordered from a website, received at home and assembled together to create a lamp (figure 3). A master token with the type of lamp would be needed and then the attributes could be attached to it, changing color, size, material, and so on. Since the tokens are portable, they could be placed in context. Then, the coupled tokens can be used to project the hologram of the lamp.

Figure 3. Tokens prototype

The second was a tablet application with an Augmented Reality (AR) plugin to show a 3D model of the customized lamp into context. The app could provide a catalogue from which the user could collect the items he like. Augmented reality would be used to pick items, textures or shapes from the real world. Furthermore, users can also select colors, shapes and other attributes from the ones readily available in the app. At the end the lamp could be visualized into context using augmented reality.
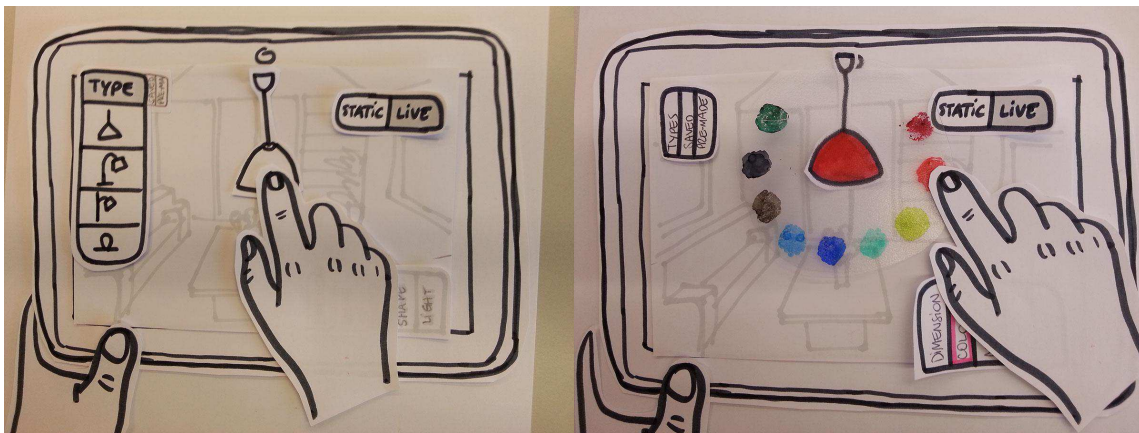

Figure 4. Augmented reality prototype

After assessing the advantages and disadvantages of the two options, the second idea was chosen. The technology required to implement the tablet app with AR is already available, whereas hologram technology is still in development. Besides, holograms can be better seen in an environment with limited lighting, and without lighting the context might be out of sight. These the two were the main reasons why the tablet was chosen. In the next section, a detailed description of the application will be given.

3.2. DESIGN

A tablet app with augmented reality is an idea that can be implemented in the near future. Given the income and affinity with technology of the target users, it is probable that most people in our target group already own a

tablet. It also offers the possibility of fulfilling all the requirements. In the following paragraphs, a detailed description of the design of the application is given.

TECHNOLOGY

A tablet is portable, and together with augmented reality and 3D models, it allows for customization in context.

CUSTOMIZATION PROCESS

The customization process is not following a strict structure. Users have the freedom of choice on where to start and the order in which they customize the different characteristics of their lamps. The minimum required element that have to be chosen to start, is the lamp type and place it into context.

The lamp type can be chosen by picking pre-designed Fraai-Werk lamps, or directly in the lamp type menu. In the case of pre-designed lamps, all the attributes are already selected and the users can change them in any order they want. In the case of choosing a lamp type to start the customization from scratch, all the attributes have to be chosen before ordering, but the order in which they select them does not influence the outcome.

The placement into context is done by using augmented reality and air gestures either in front or in the back of the screen. The Augmented Reality mode is called "Live"-mode. Since AR requires that the user holds the tablet as a camera, it can be tiring after a while. Therefore, a "Static"-mode was also included. In the Static mode, the system can take a picture of the context and use it as a background of the application, so that the user will see the context at all times.

USER INTERFACE

The user interface background consist of a view of the room where the lamp will be placed. The central element is the lamp that is being customized.

Most of the interactive elements are located at the edges of the screen to ensure that users can focus on the lamp and the context and to reduce as much as possible the visual clutter around it. Only attribute levels are displayed close to the lamp to let users easily try the different options. These can be hidden at any moment.

The location of interactive elements at the edges considers the areas where hands are placed to hold the tablet, in order to avoid that users press them accidentally.

INTERACTIONS

All the interactions with the app are standard gestures used on touch screens. The only exception is the placement of the lamp. As mentioned before, to place the lamp in AR, air gestures are necessary. The air gestures enable users to place their lamp in a tridimensional space. Furthermore, we aimed to avoid confusion between placement of the lamp (air gestures) and changing the size of the lamp (pinching).

RATIONALE

The requirements gathered from the user research were translated into features and design specifications for the customization tool.

LAMP IN CONTEXT

To make sure that the lamp designed by the user delivers a high preference fit (Requirement 1, R1), the app enables customization in context. In this way, users can visualize the lamp they will order already in the room where they would place it (R5a).

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LIVE AND STATIC VIEW

To enhance the preference fit (R1) and also facilitate the post-editing and iteration possibilities (R8), the app provides two different views to users. In live view the app opens the phone's camera to enable different viewpoints of the lamp. Using this mode, users can move around the room and see the lamp from different perspectives and even get closer to see better the materials, shape and structure (R7). On the other hand, the static view provides them with the option of fixing one particular view of the room and the lamp to customize it. The changes between these two views can be done at any moment.

CUSTOMIZATION

MENU (ATTRIBUTES):

To let users customize the aesthetics of the product (color, material, shape), the lamp type, the lamp purpose and the light type (light settings), a customization menu is provided (R2, R5d). Not all possible attributes are available to facilitate the decision making process (R3 and R11). As the menu is always available on the UI, it also provides an overview of what they can customize (R11, R5c).

ATTRIBUTE LEVELS:

To support customization in context, the levels of each attributes are visualized close to the lamp. In this way, users can try alternatives and choices in context (R1 and R6). All levels for each attribute are shown at the same time to give an overview of the possibilities (R5c). Options are limited to support decision-making (R3 and R11).

PRE-DESIGNED ALTERNATIVES

The app supports different types of users (R12) and provides starting points for them (R4). The pre-designed alternatives are lamps already designed by the company and users can directly buy them or use them as a starting point to customize their own lamp. This feature also supports users when looking for inspiration (R5b).

USERS' DESIGNS

To enable post-editing and iteration (R8) and also enable users to compare different versions (R9), the app automatically saves users' designs.

LAMP REPRESENTATION

The app enable users to visualize a prototype of their lamp (R5e). The realism of the lamp representation increases during the design process (R6).

ADVICE

To increase the chances of high preference fit (R1) and support different novice users (R12), the app provides advice during the customization process. This feature aims to represent in a way the designer's help by providing feedback and tips on the users' choices (R10).

PRICE VISUALIZATION AND ORDERING

The application provides information about the price of the lamp and how it changes according the choices made during the customization process. This supports users in decision-making (R11).

4. EVALUATION

The aforementioned design was improved following a user-centered design (UCD) approach. By using UCD, we strive to enhance this initial design and ensure its usability. The UCD process was used iteratively, using prototypes of different fidelities. Namely, low-fi, hi-fi and a video prototype. First, we used a paper prototype to test the lamp customization process, the general layout of the system, the understandability of icons, and the main interactions. Second, a hi-fi prototype was used to test the improved layout, interactions and final visual design. Finally, a video prototype was built to show the final concept after including the improvements from the previous evaluation. In the following sections this process will be explained in detail.

4.1 LOW-FI PROTOTYPE

A low-fidelity paper prototype of the tablet app was built and tested in four iterations. After each iteration, the tool was adjusted according to the results.
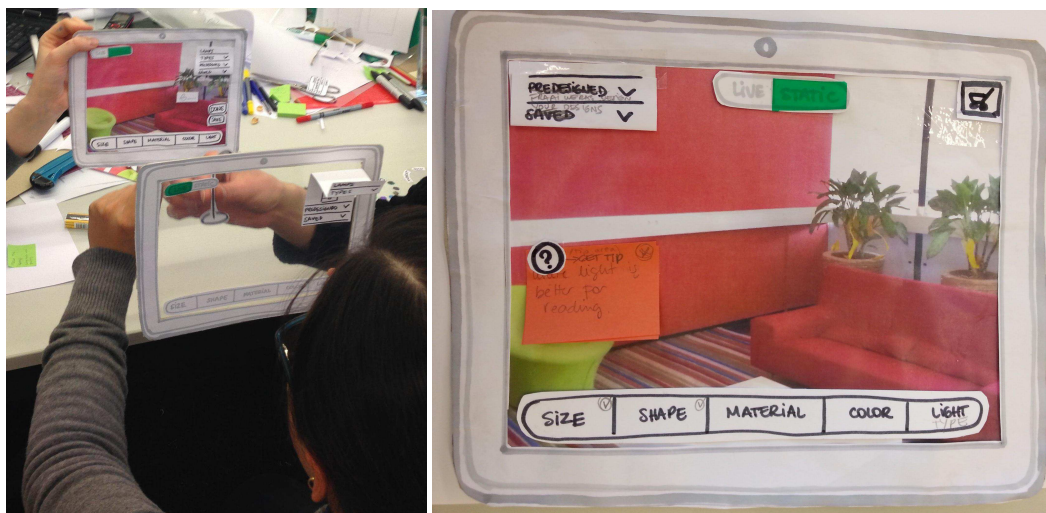

Figure 5. Paper prototype

4.1.1 METHODS

PARTICIPANTS
10 participants participated in the evaluation (average age: 26.7, SD: 2.58). All of them were employees of the Eindhoven University of Technology. Five participants took part in the first iteration, two in the second, two in the third and one in the last iteration.

PROCEDURE
The sessions were conducted in two rooms decorated as living room. Three experimenters were in the room. One facilitating the experiment, the second acting as the system, and the third taking notes.

Participants were welcomed, and a general introduction of the test was given. They were guided through a scenario, where they had to customize a standing lamp (see protocol in appendix A4). The scenario included placing the lamp in a specific point of the room using the Live mode, changing its color, shape, size and material. Furthermore, participants were asked to customize the light for reading.

Four iterations were made, and in between each of them, the problems encountered by the users were fixed in the prototype, so that in the next iteration, the new participants saw an improved design version.

IMPLEMENTATION

All interface elements were prototyped using paper, as shown in figure 6. Cardboard and transparent films were used to simulate a tablet. Experimenter changed the elements manually as the user interacted with them. From the second iteration, paper elements were superposed on a tablet, to give users the sensation of weight. Furthermore, the camera of the tablet was used to simulate AR. While the camera was on, the experimenter would move the lamp behind the screen to respond to user's air gestures.
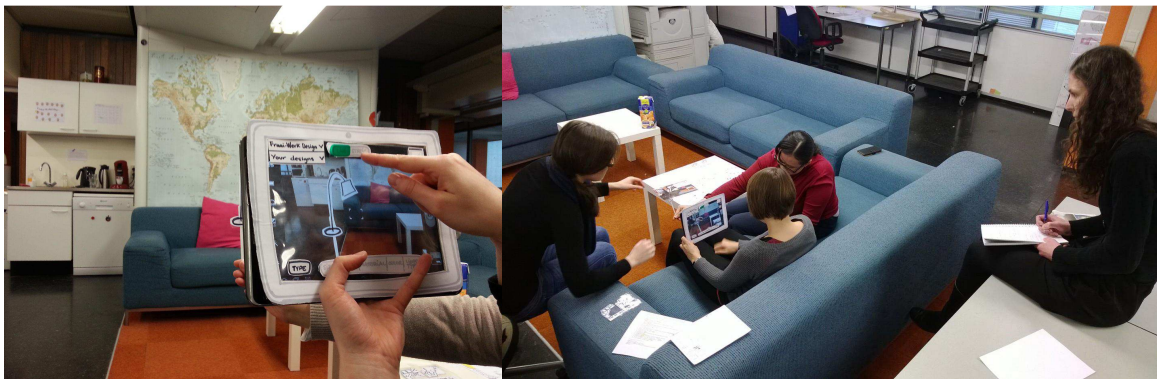

Figure 6. Setup and prototyping AR and Air gestures

4.1.2. RESULTS

During the four iterations different problems were identified. We tried different alternatives to solve them. Majority of them were solved and the solutions were applied in the next hi-fi iteration.

LAMP IN CONTEXT

Users understood the idea of having the lamp in context but positioning was not an easy task. Moving the lamp to the left, right, up or down (y- and z-axes) by tapping on it was not a problem. The difficulty was to move the lamp in terms of depth (x-axis). Different alternatives were tried: first textual instructions were provided, which were then enhanced adding visual instructions. The idea of interacting with air gesture interactions, both behind and in front of the tablet, was not clear. Many users sticked to traditional tablet interactions and tried to pinch in and out to change the depth position of the lamp. The ones that did try gestures, they tended to physically grab the paper lamp to place it.

Besides, it was not clear for them how to confirm the lamp placement. In the final iteration we incorporated a wizard that leads the users step by step through the lamp placement.

CustomizaTion

Main menu (attributes): users had difficulties to predict what certain menu items referred to. We observed ambiguity on the labels "color" (users did not know if it also involved light color or only material colors), light and type. The two latter were re-labeled as "lamp type" "light settings".

Lamp type was in the first iteration together with Fraai-werk designs. The two functionalities were grouped as starting points. As this grouping was not intuitive, the lamp types were moved to the customization menu in the second iteration.

Levels: One of the most cumbersome attribute to customize for users was the light of the lamp. The icons used to represent light setting shortcuts were not clear, and therefore they were removed in the final iteration, after trying different icons to represent general, task and atmosphere lighting. Instead, information to help them during the customization of light was relocated in the form of tips under the "Advice" feature.

The wheel and the choices distributed all around it made some users afford it as a rotating wheel. Selecting lamp parts to customize was difficult for users. In the second iteration dots were included for part selection, but they were not noticeable. The absence of color when customizing the material was confusing for users in the second iteration. This was fixed for the third iteration, on which the lamp is disassembled and its parts are shown separated.

Pre-designed alternatives

In the first iteration we had grouped the two main starting points: pre-designed lamps with lamp types. This created confusion and was changed after the second iteration, on which the "Types" panel was re-located together with the other attributes. The label "Fraai-Werk Designs" was confused with an access to the company's website. For this reason, this drop-down element was at the end by default collapsed to let users see thumbnails of the design and understand its aim properly.

Users' designs

In the first iteration, users could save their lamps in the "saved" panel by tapping on a button. Some participants found it difficult to find back their previous versions as they thought this panel worked as a historical one that was saving all the changes they were making, and not complete versions.

For the second iteration the panel was renamed as "Your designs". We included a button labeled "save to your designs" to make clear the connection of the button with the panel and feedback messages "your lamp was saved". But this was not a good solution either, as the possibility of losing versions was an issue mentioned by users. The way this panel worked was annoying for them because they expected the app to save changes automatically.

Price visualization and ordering

It was not clear for users why the order button changed its status from inactive to active at a certain point during the customization process.

In the first iteration users could order a lamp even if they had not finished its customization. In this case, the app was showing them a message stating that they had not specified certain attribute levels and that they could accept default values for them if they wanted to continue to order the lamp.

In the second iteration this was changed. All attributes started to be compulsory and needed to be customized in order to be able to buy the lamp. From the third iteration the customization progress is shown in the

customization menu using check marks. Users mentioned the difficulty to properly understand the price variations; they found it a nuisance.

4.2. HI-FI PROTOTYPE

Based on the results of the evaluation of the low-fi prototype a hi-fi prototype was built and tested.

4.2.1. METHODS

PARTICIPANTS

6 participants took part in this final evaluation. The average age of the participants was 27.17 years (SD = 2.23). They were all familiar with typical interactions used on tablet devices, however, they varied in the frequency of tablet use. 5 out of 6 participants recently moved into a new apartment/house or are planning to move soon. Therefore, furnishing and buying lamps was a relevant topic for most participants.

PROCEDURE

The evaluation of the hi-fi prototype was conducted in a home-like atmosphere by one facilitator and one person taking notes and handling the camera. One sessions took around 30 minutes. After welcoming the participant and an introduction four sections followed: (1) preliminary interview questions, (2) evaluation of the customization tool, (3) interview and (4) questionnaires. Using the hi-fi prototype, participants had the task to create a lamp. As only selected functions and options were implemented in the prototype, participants followed this specific scenario:

1. Create new lamp
2. Choose lamp type
3. Place the lamp.
4. Get inspiration from existing designs
5. Continue customizing the design that you already started.
6. Change shape
7. Increase size
8. Choose material for scaffolding and shade
9. Adjust the light settings
10. Choose color of lamp shade

After finishing the scenario, participants received a box with the real lamp, that was customized.

PROTOTYPE

For developing the high-fi prototype two programs were used. Proto.io prototyping software was used to develop a website that simulated a native Android tablet application enabling touch screen gestures. A Samsung Galaxy Tab3 10.1'' with Dolphin browser in full screen mode was used to display the prototype. The Augment application supported the parts of the prototype requiring augmented reality (live view). Its standard tracker was used to visualize and move the object (lamp model) during the placement process. The tracker was moved by the assisting person accordingly to the gestures of the participant. The basic lamp model was created in Blender 2.69. The finished Fraai-werk lamp models were rendered in Solidworks. The change between the live and static view was performed manually by the facilitator.

After the evaluation of the prototype and the following interview, participants filled in the System Usability Scale (SUS). Three additional questions were used to assess, if the participants enjoyed the customization process, if they think they could customized a lamp that fits their needs and their context at home. Answers were assessed on a 5-point scale from 1 (I strongly disagree) to 5 (I strongly agree). The complete protocol including instructions for the tasks, interview questions and questionnaire can be found in in Appendix A5.

Figure 7. Setup of the hi-fi evaluation

4.2.2 ANALYSIS

Main goal of the analysis was to find out the main difficulties participants had using the interface. Therefore, the videos taken during the evaluation sessions were analyzed and all problems were written down for each subtask.

For the SUS the average score over all participant was calculated. For the additional three questions, assessing if selected requirements were met, mean and standard deviation were calculated.

4.2.3 RESULTS

MAIN OBSERVED PROBLEMS

POSITIONING LAMP IN CONTEXT
None of the participants used air gestures to position the lamp. Most of the participants used the known tablet gestures dragging and pinching to position lamp. The video, that was used as an instruction for the positioning, could not communicate the air gestures and was additionally not remembered by two participants during the positioning process.

PRE-DESIGNED ALTERNATIVES
Exploring pre-designed lamps in the "Fraai-Werk designs" folder was clear for all the participants. Most of them tried to swipe through the lamps, which was intended but not implemented in that version of the prototype.

CUSTOMIZATION
Shape: For most of the participants no problems were observed while choosing the shape of the shade. Two participants however tried first to draw the shape.

Size: For most participants it was intuitive to use pinching to increase the size of the lamp. However, it was not clear that first, the part of the lamp needs to be selected by tapping on it. Further, some participants tried to increase the size by interacting with the number itself or the line indicating the height or width.

Material: Choosing the material was for most participants not a problem. However, some were surprised that the material for the lampshade and the scaffolding needs to be selected.

Light settings: no problem for most of the participants. One participant mentioned, that it is very good, that the light effect is shown, but the visualization should be more realistic.

Color: none of the participants had difficulties when choosing a color.

CUSTOMIZATION WHEEL (LEVELS)
Two participants mentioned, that the amount of choices is too limited for them.

LAMP REPRESENTATION
After unpacking the physical lamp after the customization process one participant mentioned, that the real lamp looks more stable than its representation and the other one, that the real lamp looks much prettier that in the app. The latter one said, that a 3D representation of the final lamp (which was not implemented in the prototype) would have helped to get a better impression.

MOST LIKED ASPECTS OF THE SYSTEM

CUSTOMIZATION IN CONTEXT
All the participants valued most, that the lamp can be customized in the context. Having a live and static view was highly valued.

"I like to try things before I buy them and this is possible with your tool." (participant 5)

LAMP REPRESENTATION
After unpacking the physical lamp after the customization process 4 participants mentioned, that the lamp looks the same as the visualization in the app.

"Oh, it's exactly the same" (participant 1)

INTERFACE
The interface is was perceived as intuitive, simple with a good flow. Positively mentioned were the checkboxes in the bottom menu, that indicate the progress of the customization process. Additionally, the arrangement of the levels of the attributes around the lamp was liked.

"It is nice, that all the choices are arranged around the lamp." (participant 4)

CUSTOMIZATION
Participants also valued the idea of customizing a lamp itself. The felt, that the system would allow them to customize a unique lamp, that cannot be found in a store.

"I think the system would enable me to create the lamp I like." (participant 2)

The average System Usability Scale score from all studies is M = 83.75 (SD = 8.91). According to Bangor et al. (2008), "better products" reach a SUS score between 70 and 90. Considering the low number of participants the here achieved test score needs to be interpreted carefully.

All of the participants enjoyed the process of customizing the lamp (M = 4.67, SD = 0.52), they believed that this system would help them create lamps that fit their home (M = 4.67, SD = 0.52) and their needs (M = 4.5, SD = 0.52). The maximum value of the scale is 5.

4.3. DISCUSSION AND FUTURE EVALUATION WORK

The methodology followed during the design process allowed us to test the concept, interface and interactions, to ensure that the final app is understandable, easy to use and enjoyable. However, due to the amount of all possible combinations of chosen options, we decided to test the prototypes using a fixed set of tasks and scenarios. This decision constraints the possibilities to test preference fit, because users do not have the freedom to choose whatever they want. However, during the hi-fi prototype evaluation, we devised a method to test it indirectly. At the end of the customization, participants received the real version of the lamp represented in the application. Most participants indicated that the lamp was quite similar to the app's representation. This suggests that the level of fidelity achieved with the prototype is enough to avoid false expectations, at least for the attributes related to the looks of the lamp. To achieve a good level of fidelity it is necessary to consider the quality of the images used to represent the context. A possible limitation might be the resolution of the camera available in the tablet, however, the odds are that the limitations of the technology will diminish with time. As virtual representations of the customized lamp increase in quality, misconceptions are avoided, trust in the app is improved and preference fit can be ensured, indirectly.

Although the representation of the looks of the lamp was accurate enough, the light settings were not correctly visualized. The projection and reflections of the light into the room were not prototyped. Future work should test the fidelity of the light representations and its impact on the preference fit.

Another important factor to achieve preference fit in our design is the visualization of the lamp in context. To achieve this, the virtual representation of the lamp had to be placed using AR. This was prototyped using a Wizard-of-Oz technique and the phone's camera, enabling us to quickly test the app. However, a drawback is the lack of synchronization between the user's gestures and the response of the prototype. As result from the inaccurate feedback provided by the prototype, most participants could not understand that they had to use air gestures instead of regular tablet gestures. Despite this fact, we assume that if the participants are provided with timely feedback, they will be able to learn the air gestures. At the moment, it is just a new type of interaction they do not imagine they can do with a tablet. Future work should address this assumption by testing the concept with a working prototype. In order to better represent these novel interactions with the Live-mode of the design, a video prototype was made. Other interactions were clear. They were based on standard gestures for tablets and most users were acquainted with tablet interaction.

By the final iteration, most of the interface layout and labels were clear and users liked them. This is due to the improvements throughout all the interactions. Especially the pre-made lamps section and the dept of the menu-wheels. The light settings menu understandability was improved by removing the shortcuts to pre-defined light settings. These shortcuts were transformed into tips to the user. For example, Instead of having a predefined color and intensity for reading light, a tip will be shown describing what kind of light is good for reading.

The behaviour of the system was correctly interpreted by the users. Beside the auto saving patterns, the price changes and the aforementioned problems with the air gestures.

For the last version of the design, saving will be done automatically. However, this was not tested with the hi-fi prototype. The frequency of the autosaving should therefore be tested in future work. It could be coupled to every change made or done from time to time.

Price visualization showed changes in price every time an attribute was changed. This was intended to show, in an indirect manner, the costs of changes in every attribute. Users seemed not to realize this, or preferred to have a more detailed description of the costs of each change. A possible explanation of the lack of awareness on the origin of the price changes, is that the price is placed in the periphery. Including the price is quite important given the user requirements, however, deciding the best manner to communicate it to the user is left for future work and should consider marketing strategies and the consumer's behaviour.

5. FINAL DESIGN

5.1. CUSTOMIZATION PROCESS

The app starts with a "Wizard mode" to guide the user through steps required to begin the customization and help him in exploring the tool (R5c).

WIZARD
To support users in recalling their own needs, the wizard first asks them choose a lamp type and set it in context (R5a). It guides them to a correct placement of the lamp which is crucial for successful customization. The placement into context is done by using augmented reality and air gestures. The Augmented Reality mode is called "Live"-mode. After the placement is finished, the system can return to a Static-view in which the context is represented by an automatically taken static photograph of the space. Then the wizard leads the user to the point where they can choose between different starting points (R4). They can then decide whether to explore ready pre-designed lamps or start from scratch with their own design.

Since now on the wizard mode is finished and they can decide themselves on the order of the steps they want to follow (R5).

CUSTOMIZATION
Regardless of which option they choose - to start from scratch or from a ready lamp the users have the same customization possibilities. In order to reach a finished product they need to specify each of the following: lamp type, its shape, size, materials of each lamp part, lamp color and light settings. If they choose to customize from scratch - they need to specify each of the attribute values themselves. In case of Fraai Werk designs those values are already specified but users have the possibility to make changes. The choices they make are automatically saved throughout the process. At any time they can start designing a new lamp or explore Fraai Werk designs. To support the decision making process the system offers accurate tips for each of the sections and choices they make. At each stage of the process the users can choose to switch from a static to live view in order to see a more realistic model of the lamp through augmented reality in their actual space.

5.2. USER INTERFACE AND INTERACTION

The final UI of the app includes the following elements and interactions (Figure 8):

"FRAAI-WERK DESIGNS" PANEL

This panel enables users to browse different pre-designed lamps. The alternatives are filtered and ranked according to the lamp type chosen by the user and his/her behaviour. Users can either tap on the thumbnails or swipe on the lamp in context to explore the alternatives. Thumbnails from this panel can be dragged and copied to "My designs" panel creating a new slot there. This panel is by default collapsed but it can be hidden at any time.

"MY DESIGNS" PANEL

This panel keeps the users' designs. Users can create as many designs (or saving slots) as they want. Their designs are automatically saved. Users' designs can also be browsed and hidden in the same way that Fraai-Werk designs are. A green highlighter indicates which is the thumbnail that is being visualized in the context.

AUTO-SAVING FEEDBACK

Feedback on the saving status is shown below "My designs" panel. The feedback makes explicit when the app is "Auto-saving" and when the lamp is "Saved". The green selector on "My Designs'" panel indicates on which saving slot the changes are being saved.

"LIVE" AND "STATIC" VIEW BUTTONS

Users can tap on the live or static view buttons. In static view, the lamp and context are fixed, whereas in live view the lamp is fixed to a physical position and therefore they have to point at the specific area to be able to see it.

ORDERING AND PRICE INFORMATION

The area includes the price of the lamp (which changes during the process), the "Add to cart" button (to add one design that is ready to order) and cart button (to continue to order the lamp).

ADVICE

The advice area automatically shows tips and messages about the customization choices. It guides users by providing additional information on the choices they make (i.e. "This shape is good for high intensity lighting") and it aims to help them when they try too many alternatives and do not make a decision (e.g. "Red seems to match your room").

ATTRIBUTES MENU

The buttons included in this menu are "Lamp type", "Shape", "Size", "Material", "Color" and "Light settings". Attributes that were already customized are checked mark to show the status of the progress in the customization process.

ATTRIBUTES LEVELS

The options to customize each attribute are shown in two different ways:
> a. on the lamp in context (e.g. users have to tap on a lamp part to select it and make changes on it)
> b. on the wheel surrounding it (which provides options with text or icons)

In only one case, in light settings, different wheels are overlapped for the customization of light color or intensity. In this cases, a back button is included.

The background of the app is the context on which the lamp will be placed. It can be a picture (in the static mode) or the camera function (in the live view)

REPRESENTATION OF THE LAMP

The lamp is shown in different ways during the customization process. Its realism level increases during the customization processes as more attributes are customized.
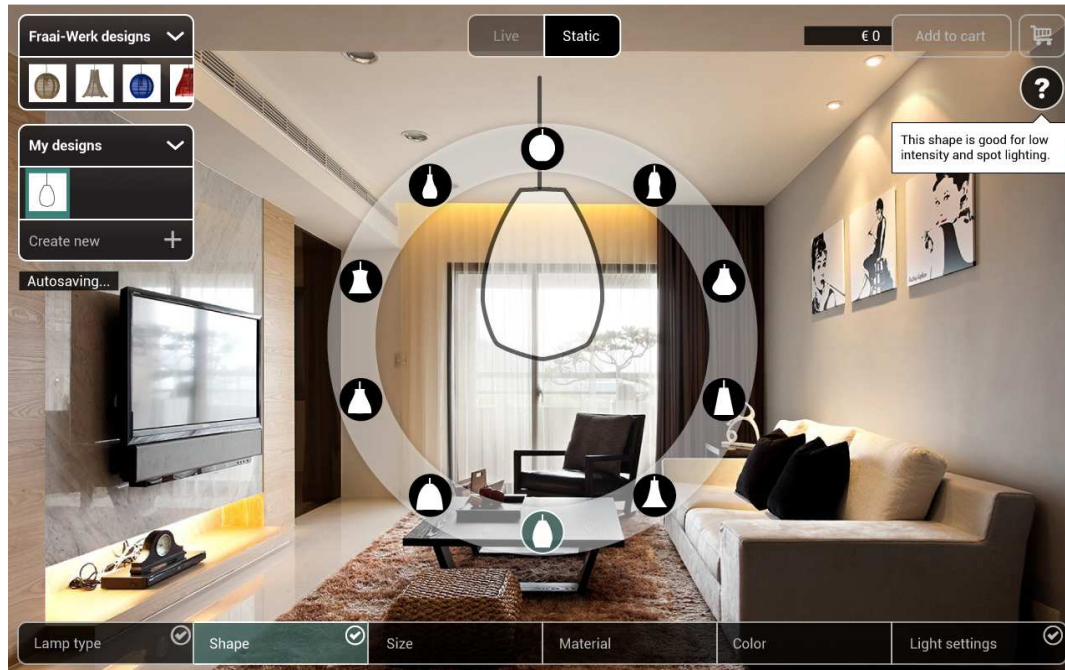

Figure 8. Screenshot of the app's User Interface: customization of the lamp shape.

5.3 LIMITATIONS OF THE DESIGN

The main limitation of the current design is the fixed amount of shapes that the user can choose. Possible alternatives to solve this issue are: (1) to allow them draw their own shapes or (2) combine our design with the current Fraai-Werks approach to modify shape points. Further research should be conducted on the optimum number of points that the user should modify.

As mentioned in the discussion, there are still challenges in the visualization of light effects on augmented reality. For our prototype this was not possible to implement, but it can be tested with a working prototype. Other challenges with augmented reality tools are handling occlusions, sizes, and image jittering. However, it is just a matter of time until the state-of-the-art of AR technology can solve them.

Another limitation is that the interaction to let users remove versions from "My designs" panel. This point was not designed and should be considered before implementing the product.

5.4 RECOMMENDATIONS FOR IMPLEMENTATION

As described in section 4.2.1, the concept was prototyped using a combination of a website generated with the Proto.io prototyping tool and an AR app called Augment. Proto.oi allowed us to use touch gestures for the Static-mode, and Augment app provided a tool to simulate the Live-mode. Finally, the air gestures to position a lamp in Live-mode were prototyped using the Wizard-of-Oz technique.

Although the HTML/Javascript prototype generated by Proto.io was good enough for testing, its responsiveness would be too slow for the real App. We expect that the system response will be similar with other tools that allow HTML to be compiled as an app (PhoneGap, Titanium). Therefore, our suggestion is to program a native app.

The Augment app was also robust enough for testing. We chose it because it has both the option to use a tracker and regular tablet gestures to position a 3D model into the real space. The aim of our design is to use gestures instead of a tracker, because gestures are more comfortable to use. However, using a tracker is, currently, more robust than using gestures. Therefore, we suggest to implement the Static-mode first, and to use a tracker in the first stages of implementation of the Live-mode. If a tracker is to be used, other AR libraries or SDKs for AR might be considered.

To implement air gestures, there are several options available. The latest Samsung smartphones already use them with help of an infrared rise sensor. Another option to consider is Leap Motion.

Finally, the visual design (including position, labels and icons), the options available in each attribute level, and the order in which the wizard teaches the user how to use the app were carefully tested and are ready to be implemented. As discussed before, the only exceptions are the light representations, the autosave behaviour and feedback, and price visualization.

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